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Carderock Division
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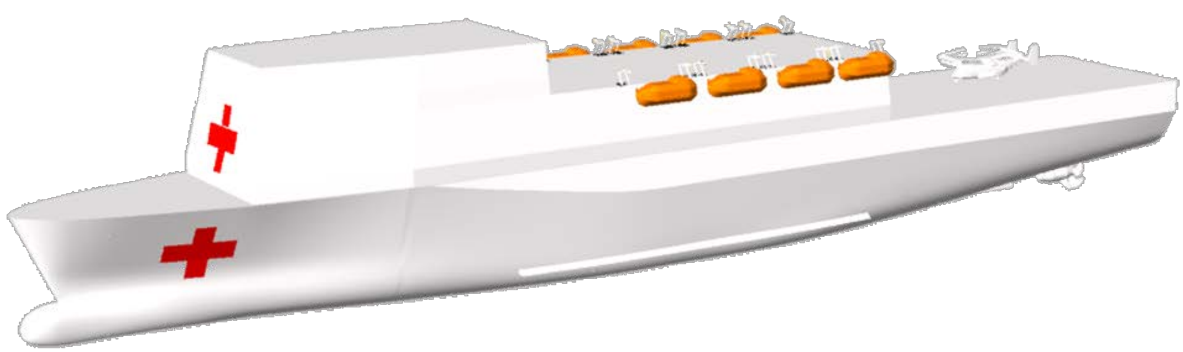
Naval Architecture and Engineering Department

Technical Report

Development of the Hospital Ship Replacement (HSR) Concept – Maximizing Capability & Affordability

by

Jennifer Kelso, Ashley McClelland, Heather Tomaszek, Chad Verbano



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The Center for Innovation in Ship Design (CISD) requested a design effort to refine and expand upon a previous development of a concept that could serve as a replacement for the existing hospital ships, USNS Mercy (T-AHS 19) and USNS Comfort (T-AHS 20). These ships are over 35 years old and are expected to be replaced once they are at the end of their service life. The Navy Bureau of Medicine and Surgery (BUMED) have stressed the need for modular medical facilities and amphibious support to enable increased ship-to-shore patient transfer and to extend medical capabilities ashore. The main objectives of
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this study include the development of the previous Hospital Ship Replacement (HSR) concept to incorporate improvements to general arrangements and the patient transfer interface, and to apply commercial design standards to result in a more producible and lower cost ship.

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Acronyms

ABS	American Bureau of Shipping
ACV	Air Cushion Vehicle
AFM	Army Field Manual
BUMED	Navy Bureau of Medicine and Surgery
CISD	Center for Innovation in Ship Design
CRNA	Certified Registered Nurse Anesthetist
CSSR	Communications System Segment Replacement
D-G	Diesel generators
DDS	Design Data Sheet
HA/DR	Humanitarian Aid/ Disaster Relief
HM	Hospital corpsmen
HSR	Hospital Ship Replacement
HSR(R)	Hospital Ship Replacement Revised
HVAC	High Voltage Alternating Current
ICU	Intensive Care Unit
LBP	Length Between Perpendiculars
LCAC	Landing Craft Air Cushion
LEAPS	Leading Edge Architecture for Prototyping Systems
LOA	Length Overall
LPD	Landing Platform Dock
MCESS	Marine Corps Expeditionary Shelter System
MSC	Military Sealift Command
NAVSEA	Naval Sea Systems Command
ROC/POE	Required Operational Capability and Projected Operational Environment
SMP	Ship Motions Program
SOLAS	Safety of Life at Sea
SS	Sea State
SWBS	Ship Work Breakdown Structure
USNS	United States Naval Ship

Abstract

The Center for Innovation in Ship Design (CISD) requested a design effort to refine and expand upon a previous development of a concept that could serve as a replacement for the existing hospital ships, USNS Mercy (T-AHS 19) and USNS Comfort (T-AHS 20). These ships are over 35 years old and are expected to be replaced once they are at the end of their service life. The Navy Bureau of Medicine and Surgery (BUMED) have stressed the need for modular medical facilities and amphibious support to enable increased ship-to-shore patient transfer and to extend medical capabilities ashore. The main objectives of this study include the development of the previous Hospital Ship Replacement (HSR) concept to incorporate improvements to general arrangements and the patient transfer interface, and to apply commercial design standards to result in a more producible and lower cost ship.

Administrative Information

The work described in this report was performed by the Center for Innovation in Ship Design (CISD, Code 8202) of the Naval Architecture and Engineering Department at the Naval Surface Warfare Center, Carderock Division (NSWCCD). The work was internally funded by CISD as a ship design training exercise to develop a new ship concept.

Introduction

Objective

The primary aim of this concept design study was to refine and expand upon a previous concept design that is capable of replacing the U.S. Navy's existing hospital ships. The previous Hospital Ship Replacement (HSR) (Allison, H., Lovdahl, B., Mehrvarzi, C., and Piks, R, 2011) design incorporated the following main objectives:

1. provide immediate and mobile medical services to deployed military both ashore and afloat;
2. provide mobile medical services for humanitarian aid and disaster relief in emergency situations;
3. maximize patient throughput.

Several issues and new design areas were highlighted in the first study. This study was proposed, therefore, to address these issues and had the secondary aim of revising and developing the original HSR concept to overcome some of the identified shortcomings of the currently in-service ships, including:

1. reflecting the overall change in mission since the design of the current in-service ships;
2. offering flexibility in the utilization of available spaces (modularity);
3. providing improvements in maneuverability and zero-speed seakeeping;
4. providing improvements in patient access via small boat transfer;
5. providing modern, flexible , higher capacity auxiliary systems (fresh water, oxygen, etc).

The resulting updated design is referred to within this study as the HSR Revised – HSR(R).

Background

The current U.S. Navy hospital ships are the *Mercy* (T-AH-19, Figure 1) and *Comfort* (T-AH-20). These ships were constructed in 1975 as *San-Clemente* Class oil tankers before being converted and subsequently commissioned as hospital ships in 1986. The principal characteristics of the *Mercy* Class are listed in Table 1.

The primary mission of the *Mercy* Class is to provide mobile medical and surgical services to support forces deployed ashore. These ships are engaged not only in combat casualty care, but also disaster relief and planned humanitarian operations within and outside the continental United States. While the two are considered secondary in priority, planned Humanitarian Aid and Disaster Relief (HA/DR) are expected to dominate the future missions of hospital ships. This re-focus in mission priority is the driving factor in the redesign of medical facilities and arrangements.

During summer 2011, a preliminary concept for a future HSR (Figure 2) was developed. The study focused on existing hospital ships' shortcomings, which including excessive draft, limited oxygen and freshwater production, and limited modularity of key medical spaces. The USN LPD-17 was chosen as a parent hull form for the HSR. Principal characteristics for the concept are found in Table 2.

Table 1: T-AH Principal Characteristics

***Mercy* Class Characteristics**		
Displacement, full load	69,360 LT	[68,265 mt]
Length, overall (LOA)	894 ft	[272.5 m]
Beam	105 ft	[32.0 m]
Draft	33 ft	[10.1 m]
Mission length	30 days	
Sustained speed	17.5 knots	
Total Installed Power	18.3 MW	
Power & propulsion	2 × boilers 2 × steam turbines single shaft	
Accommodations	1,000 patients 61 civilian crew 1,214 medical personnel	

Table 2: HSR Principal Characteristics

HSR Principal Characteristics		
Displacement, full load (LT)	25,000 LT	[24,605 mt]
LOA	684 ft	[208.5 m]
LBP	668 ft	[203.6 m]
Beam	105 ft	[32.0 m]
Draft	23 ft	[7.0 m]
Depth	62.3 ft	[19.0 m]
Mission length	30 days	
Sustained speed	20 knots	
Total installed power	35 MW	
Power & propulsion	4 × Wartsila 18V32 Gensets Integrated Power System Twin azimuthing pods	
Accommodations	500 patients 72 civilian crew 428 medical personnel	

Figure 1: USNS Mercy

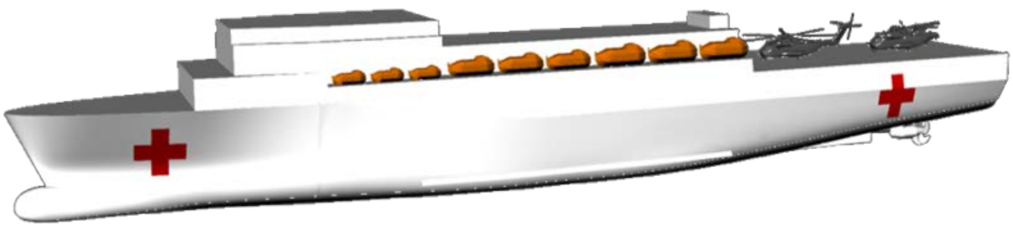

Figure 2: HSR Replacement

The objective of this project is to revalidate, refine and expand upon the previous design effort in the areas listed below.

1. **Evaluation of seakeeping requirements –** although the HSR incorporated a means of reducing motions at anchor, the seakeeping requirements needs to be quantified so that a trade study of other motion-damping systems can be conducted.
2. **Producibility –** producibility studies have identified numerous design features that enhance producibility and hence should reduce ship design and build cost. These features were not fully reflected in the original HSR design.
3. **Structural analysis –** Since the HSR hull form assumes the LPD-17 as a parent hull, the structural design needs to be commercialized in order to complement the hospital ship's missions as well as to potentially reduce cost. The HSR(R) structure should be designed to commercial standards and classed under the ABS Steel Vessel Rules.

4. **Launch and recovery systems –** an evaluation of patient transfer interface should be considered. Reducing the size or eliminating the well deck of the LPD-17 and its extensive ballast system should offer weight, volume and cost savings to a HSR(R).
5. **Ambulance Alternatives –** the importance of surface ambulances and the well deck have been identified in this design. Further evaluation of ambulance alternatives and the related launch and recovery systems are necessary in order to efficiently integrate patient transfer by sea.

Additional requirements stipulated by CISD are listed in Table 3. Not all required characteristics are listed explicitly. The premise of this project is to investigate and determine appropriate characteristics and requirements that can serve as a basis for future design work.

Table 3: CISD Design Requirements

<table>
<tr><th></th><th>Characteristic</th><th>Threshold</th><th>Objective</th></tr>
<tr><td rowspan="6">PERFORMANCE</td><td>Displacement</td><td colspan="2">25,000-30,000 LT</td></tr>
<tr><td>Range</td><td colspan="2">13,420 nm</td></tr>
<tr><td>Draft</td><td>33 feet</td><td>< 33 feet</td></tr>
<tr><td>Sustained Speed</td><td>18 knots</td><td>> 18 knots</td></tr>
<tr><td>Sea State Operability</td><td>SS5</td><td>-</td></tr>
<tr><td>Sea State Survivability</td><td>SS8</td><td>-</td></tr>
<tr><td rowspan="7">MEDICAL FACILITIES</td><td>Intensive Care</td><td colspan="2" rowspan="7">To Be Determined by Team</td></tr>
<tr><td>Recovery</td></tr>
<tr><td>Intermediate Care</td></tr>
<tr><td>Minimal Care</td></tr>
<tr><td>Reception/Triage</td></tr>
<tr><td>Operating Rooms</td></tr>
<tr><td>X-Ray Units</td></tr>
<tr><td rowspan="3">MANNING</td><td>Crew</td><td colspan="2" rowspan="3">To Be Determined by Team</td></tr>
<tr><td>Medical Staff</td></tr>
<tr><td>Flight Operators</td></tr>
<tr><td rowspan="3">PATIENT or STORES TRANSFER</td><td>Air – Land/launch</td><td>2 × CH-53</td><td>2 × CH-53 & MV-22</td></tr>
<tr><td>Hangar</td><td>1 × CH-53 or 2 x H-60</td><td>1 × CH-53 & MV-22</td></tr>
<tr><td>Sea – Ambulance vehicles</td><td colspan="2">To Be Determined by Team</td></tr>
<tr><td rowspan="2">SUPPLY GENERATION</td><td>Fresh Water</td><td>100,000 gal/day</td><td>> 100,000 gal/day</td></tr>
<tr><td>Oxygen</td><td>366,830 l/day</td><td>> 366,830 l/day</td></tr>
<tr><td rowspan="2">OTHER</td><td>Lifeboats</td><td>SOLAS Compliant</td><td>SOLAS & Organic to ship</td></tr>
<tr><td>Boat Handling</td><td colspan="2">Capable of transferring personnel, cargo, and injured patients</td></tr>
</table>

Ship Design

Concept Summary

The HSR(R) concept is shown in Figure 3. Principal characteristics are found in Table 4.

Figure 3: HSR(R) Concept

Table 4: HSR (R) Principal Characteristics

HSR(R) Principal Characteristics		
Displacement, full load	25,060 LT	[24,664 mt]
LOA	684 ft	[208.5 m]
LBP	668 ft	[203.6 m]
Beam	105 ft	[32.0 m]
Draft	23 ft	[7.0 m]
Depth	62.3 ft	[19.0 m]
Mission length	30 days	
Sustained speed	20+ knots	
Total installed power	41.2 MW	
Power & Propulsion	4 × 8.64 MW D-G sets 2 × 3.84 MW D-G sets 1 × 1.48 MW emergency Integrated Power System Twin azimuthing pods Bow thruster	
Accommodations	500 patients 140 civilian crew 868 medical personnel 40 Security Detachment	

Hull Form

A monohull was chosen as an optimal, and conservative, solution for integrating multiple forms of ship-to-shore patient transport as well as providing the required internal volume needed for a hospital ship. LPD-17 was previously chosen as a parent hull form, and no additional changes were made to the geometry of the ship. Detailed information on hull selection can be found in the previous HSR report (Allison, Lovdahl, Mehrvarzi, and Piks, 2011).

Medical Facilities Breakdown

The size and capacity of hospital ships are typically described by the quantity of patient beds it obtains. It was previously decided to design a 500-bed hospital ship through consultations with BUMED. Although this change may appear to significantly impact the overall mission capability, the HSR(R) medical facilities are designed to have a more efficient flow of patients and a greater patient throughput which allows the ship to accommodate a similar number of patients as the *Mercy* Class during its most common missions, but within a smaller ship. The HSR(R) should be capable of receiving patients, treating patients, and being discharged off ship within 72 hours of arriving. Details of HSR(R) beds and medical facilities are listed in Table 5.

Table 5: HSR(R) Medical Facilities

	T-AH 19 & 20 (number of beds)	**HSR(R) Readiness State II HA/DR (number of beds)**
Intensive care	80	60
Recovery	20	15
Intermediate care	400	320
Minimal care	500	105
Total bed capacity	**1,000**	**500**
Reception/triage	50	35
Operating rooms	12	6
X-Ray	4	3

HSR(R) medical facilities are designed for Readiness State II as specified in the Required Operational Capability and Projected Operational Environment (Department of the Navy, Office of the Chief of Naval Operations, 1997). These ratios and numbers of facilities provide a design point for a replacement concept. Designed in this manner, the ship can provide tailored levels of surgical-intensive care, while focusing on primary care, preventative medicine and specialized procedures more readily. Modular medical facilities will address the needs of both the ship’s primary combat casualty care missions while allowing re-configuration for HA/DR missions.

General Arrangements

The major focus of general arrangements for HSR(R) is the medical facilities and patient flow on board. A view of the inboard profile is shown in Figure 4. Guidance from MSC and BUMED included a desire to reduce the vertical transport of patients, provide a central location for all critical care units, provide efficient flow of patients into and through medical facilities, and provide flexibility to adapt to the mission at hand, be it battle casualties, natural disaster victims, or humanitarian assistance missions.

A key consideration in developing the arrangements is grouping facilities by their mission priority. For instance, a HA mission would rely on primary care facilities, such as dentistry and physical exams. These primary care facilities are located on a single deck to minimize the movement of staff and patients while trying to accommodate that mission. By developing the arrangements in a way that centralizes care by mission, the ship can be more easily adapted for the mission at the time.

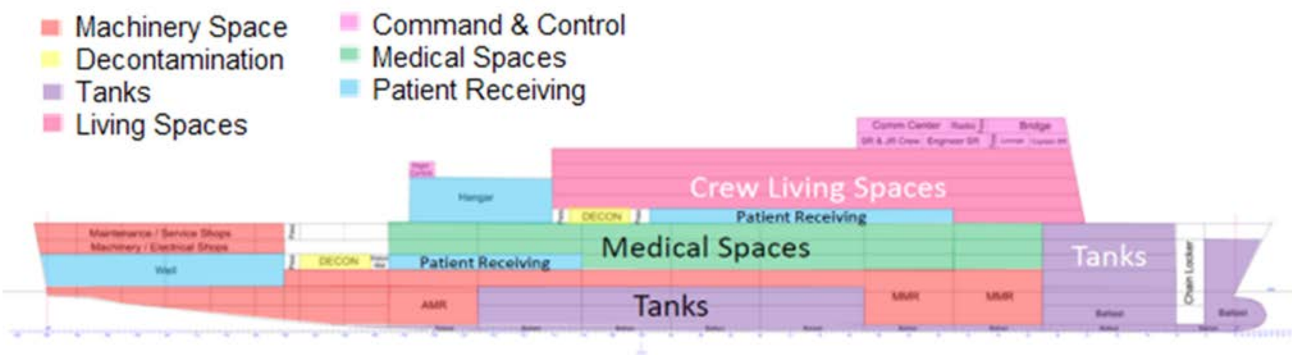

Figure 4: HSR(R) Inboard Profile

Mercy Class hospital beds are arranged in two tiers to potentially allow two patients to occupy the same footprint. However, the top-level beds are rarely used for patients due to the difficulty of transferring and treating the patient at their installed height. For this reason, the nominal 1,000-bed capacity of the *Mercy* Class realistically is a 500-bed capacity during a disaster relief mission, as orthopedic injury patients cannot be placed in top-level beds. Therefore, the HSR(R) assumes a single tier bed arrangement with the option to add a top-level bed solely to provide the ability for a family member to stay aboard with the patient.

The bed capacity of HSR(R) will match the capacity of the current hospital ships in some missions, but will require an equal or greater number of medical staff to provide adequate patient care when compared to the current *Mercy* Class.

During HA missions, which have dominated the actual operational use of the current hospital ships, the HSR(R) can accommodate the necessary number of medical personnel within current MSC habitability standards. Should larger numbers of medical personnel be needed, the cabins could be outfitted with wall-mounted fold-out beds to accommodate the additional personnel and

avoid the need for medical and civilian crew to share sleeping space during alternating shifts (often described as hot-bunking).

Two additional decks have been added to the originally proposed superstructure design to provide the area needed for crew accommodations. Without these decks, space for approximately 300 personnel is available, which is insufficient for a reasonable medical staff and crew complement. These two added decks allow for over 1,000 racks meeting MSC accommodation standards for crew, medical personnel, and assorted detachments as needed for the mission. Detailed deck arrangements are located in **Error! Reference source not found.**.

Patient Transfer

Air Support

There are limited capabilities in terms of ship-to-shore air transportation on the current hospital ships. Increasing air support for this design is vital to transport critical care patients and for its ability to access areas inaccessible by sea. Additionally, helicopters can potentially transport ISO containers and other medical supplies needed for shore assistance. In order to improve this capability, HSR(R) has incorporated several air support enhancements. The integrated flight deck and hangar design from the parent hull was retained; the large flight deck allows multiple helicopter landings and take-offs, as summarized in Table 6.

Table 6: HSR(R) Air Support Facilities

Land/Launch Spots	2 × CH-53 (Sikorsky Super Stallion)
	2 × MV-22 (Osprey)
	4 × CH-46 (Sea Knight)
Hangar	1 × CH-53 (Sikorsky Super Stallion)
	1 × MV-22 (Osprey)
	2 × CH-46(Sea Knight)

HSR(R)'s flight deck can be designed to operate MV-22s but would require similar deck design and coating measures currently been developed for other Navy ship designs to counteract the thermal effects of its exhaust systems. The hangar capabilities are limited; HSR(R) is capable of landing aerial vehicles, refueling, and performing limited routine maintenance only.

The CH-53 helicopter is an optimal solution for air support during medical operations. It offers a large payload capacity for airlifting ISO medical care containers and transporting patients. Referencing the CH-53 for patient loading configurations, the stretcher and ambulatory configurations are found in Table 7.

Table 7: CH-53 Patient Arrangement

Ambulatory	Stretcher
31	0
25	4
19	8
16	12
10	16
4	20
1	24

Amphibious Support

Several amphibious vehicles have been designed solely to be used as an ambulance vehicle. Potential amphibious craft were analyzed by their performance by using several design parameters as the basis for evaluation: vehicle speed, max patients per hour transported, and total patients transported within a twenty-four hour time period. For example, the air cushion vehicle (ACV) Griffon 2400TD hovercraft, Figure 5, offers a good mix of benefits and appears an attractive possible ambulance craft. Hovercraft specifics are found in Table 8.

http://www.griffonhoverwork.com/products/4

Figure 5: Griffon 2400TD Hovercraft

Table 8: Griffon 2400TD Hovercraft Specifications

Length (hovering)	43.9 ft	[13.4 m]
Beam (hovering)	22.3 ft	[6.8 m]
Height (hovering)	14.1 ft	[4.3 m]
Approximate obstacle clearance	2.6 ft	[0.8 m]
Max. recommended wave height	3.3 ft	[1.0 m]
Passengers (excluding crew)	25	
Maximum payload	2.4 mt	
Endurance	7 hours	
Fuel consumption	35 L/h	
Speed at full payload	30 knots	
Power per engine	0.44 MW	

The potential patient seating arrangement for Griffon 2400TD was also analyzed. In order to develop seating arrangements, data for a 95th percentile human male standing, sitting, and sitting with one leg propped was used to estimate area needed per patient. The objective was to maximize both vertical and horizontal space within the hovercraft while providing sufficient, comfortable room for patients. Patients on stretchers will have the capability of being stacked three levels high with room remaining for seated patients. The patient capacity for the Griffon 2400TD, including a combination of patient on stretchers and walking wounded patients, is estimated a total of 29. However, with a maximum payload of 2.4 tons, the ACV will be restricted by weight when it comes to passenger capacity. For verification, these patient capacity estimates were compared to seating arrangements within Marine Corps Expeditionary Shelter Systems (MCESS) and containers.

Other vehicles were studied to explore different missions as well as the maximum possible patient transport. Each amphibious craft was analyzed for estimating the maximum patient transport per hour including triage time, approach and moor, patient loading and offloading, and cast off and clear. Details of patient transport time are located in Amphibious Support. These calculations provide an overall time estimate, with the loading and unloading time requirements remaining constant per patient; additional iterations involved varying vessel speed, transit distances, and number of patients. Although the total time for loading and offloading patients is high, this assumes patients are loaded individually. For ambulatory patients, loading would occur simultaneously for all patients.

The actual patient loading and unloading would be performed by the crew. Potentially, a conveyor system could assist stretcher loading to eliminate soldier fatigue. The Four Fold

Military Stretcher was used as an example for patient loading, as seen in Table 9. The stretchers present quick, efficient means for transporting patients and loading into the Griffon 2400TD.

Table 9: Four Fold Military Stretcher

Parameter	MedEvac4 Folded	MedEvac4 Extended
Length	1.7 ft [0.5 m]	6.8 ft [2.1 m]
Width	0.6 ft [0.2 m]	1.8 ft [0.5 m]
Weight	14.3 lbs	14.3 lbs
Height	0.45 ft [0.1 m]	0.50 ft [0.1 m]
Unfolding time	6 seconds	6 seconds
Total Area	12.5 ft^2[1.2 m^2]	12.5 ft^2[1.2 m^2]

Several sea-to-ship interface options were considered to improve the overall ease and rate of patient transfer from small boats and ambulance craft. While no totally satisfactory solution was arrived by the end of the study, the key options and their features are highlighted in Table 10. Details on the advantages and disadvantages of these options can be found in Sea-to-Ship Transfer Options. Key aims were to retain the well deck benefits of the parent hull (LPD-17) while minimizing the significant impact that a full wet well would create by reducing the overall dimensions of the well deck and reducing or removing the need for a matching ballast system.

Table 10: HSR(R) Ship-to-Sea Interface Options

System	Description	Pros	Cons
SEABEE	Platform at the stern lowers from main deck to below the waterline; allows small craft to move onto the platform and be lifted up to main deck. Design originally used to lift barges.	Adaptable, no ballast required	Poor hydrodynamic characteristics, uncovered patient unloading
Wet well deck (current)	Opening at the stern is flooded by ballasting the aft end of the ship to well below the design waterline, allowing craft to power into the ship.	No redesign, adaptable, protected patient unloading	Large structure ballast needed, excess requirement for hospital
Dry well deck	Same arrangement as wet well deck but without flooding the aft end of the ship; no ballasting system required.	No ballast required, protected patient unloading	Restricted ambulance vehicles, large structure required, undefined
Reduced Size Well Deck	Same concept as wet well deck, but with a significant reduction in size to accommodate small craft.	Adaptable, protected patient unloading	Large ballast system and structural support required
Davit System	Two or more crane lift points mounted to the deck, allowing small craft to be transported to the edge of the deck and lowered back to the water.	Simplistic, adaptable, minimal hull openings required	Limited capability, unprotected patient unloading, some difficulty
'Well-Bee'	Combination of SEABEE and wet well deck, allowing the well deck platform to lower below the waterline. This allows the well to operate as a wet well without the need for an intricate ballasting system.	No ballast required, adaptable, protected patient unloading	Advanced mechanical systems needed, high risk

The proposed HSR(R) assumes the well dock to be halved in length compared to the parent hull form but retaining the width. The overall weights and volumes assume shrinkage of the ballast water system. Provision of either a dry or wet well deck area should offer significant benefits to the operability and flexibility of a future hospital ship. It is recommended that future consideration of this concept focuses on this design area to improve its definition.

Manning Estimate

The HSR(R) objective remains the same as for the current hospital ships: provide the required medical personnel to bring patients onboard, be treated, and discharged from the ship within approximately 72 hours. The required medical personnel to provide adequate treatment needed for 500 patients were estimated using the patient-to-staffing ratios in Table 11 (Negus, Brown, and Konoske, 2007). Although the bed capacity has been reduced from the *Mercy* Class, this lower number reflects the realistic availability of patient beds in many missions.

Table 11: Patient versus Medical Staffing Ratios

Department	Staff Type	Ratio
CASREC	Nurses	1 per 4 beds
	Physician	1 per shift
	HM	1 per 2 beds
OR	Nurses	2 CRNA per anesthesia provider, 1 RN circulator, 2 preoperative per table
	Physician	1 anesthesia provider, 1-2 surgeons per table
	HM	2 surgical techs in CSSR and 2 techs in OR per table; 1 anesthesia tech per 2 anesthesia providers
ICU Beds	Nurses	1 critical care nurse per bed per shift
	Physician	1 provider, internal medicine or intensivist preferred
	HM	1 HM per bed per shift, 1 resp. tech for ventilator management per 2 beds, 1 HM for supply
Isolation Ward	Nurses	1 per shift
	HM	1 per shift
Ward	Nurses	1 med-surg. nurse per 8 beds per shift
	HM	1 HM per 4 beds per shift, 1 HM for supply
Discharge Planning	Nurses	2 (1 on-board and 1 at the boat landing zone)
	HM	5 (4 on-board and 1 to travel with patients)

To support 20 recovery beds, 80 ICU beds, 400 ward beds, and 500 minimal care beds, 1,362 medical personnel are required, which is an 11% increase from current staffing on the *Mercy* Class. This percentage increase suggests that the medical staffing ratios used are accurate in predicting the necessary staffing to support medical care needed for 500 patients. The proposed HSR(R) has accommodations for approximately 868 medical personnel only. However, there are

flexible spaces that could be outfitted for overflow berthing if needed; these berthing areas would meet a lower standard than the MSC accommodation regulations.

The proposed MSC crew complement of 140 personnel is more than twice the size of civilian crew on the *Mercy* Class. This figure appears excessively high, especially with the move from a steam turbine based design to a modern integrated electrical power system (IPS), however reflects MSC's estimates to adequately man for the following features:

1) enhanced hospital messing/scullery, radio communications, and O2/N2 plant,
2) hospital laundry facilities,
3) more capable flight and well decks.

The *Mercy* Class may also carry a security detachment for certain missions. The size of these detachments can range from 15-40 personnel, as referenced by MSC. The HSR(R) assumes a detachment of 40 as a conservative space designation.

Mission Systems

Medical ISO Containers

HSR(R) has the capability of storing a maximum of 16 ISO containers. Medically outfitted ISO containers are commercially available and can house a variety of medical facilities. The containers will be stored alongside the hangar and can be airlifted to areas inland to provide immediate medical care to disaster stricken areas. Portable generators will be required to power the containers once ashore; these may also be shipped as standard ISO based diesel generators. These containers offer a solution for the need of transporting medical capabilities ashore during certain missions.

Flex Spaces

Certain spaces were designated as reconfigurable flexible spaces within the general arrangements. These flexible spaces can be used as patient care, patient holding, additional storage, or when additional berthing for medical staff is needed.

The HSR(R) incorporates several unassigned spaces. These spaces could be assigned to a range of options, including: austere additional accommodation, storage for charitable donations and other equipment brought on-board by Non-Government Organizations (NGO), or flexible office space for use a disaster relief management space by either government agencies or NGOs.

Machinery Selection

Resistance and Powering

The power requirement for the parent hull form is a topic area that was revisited during the revised design effort. LPD-17 model test data was used in order to estimate the bare hull resistance, and correlation allowance, C_A, of 0.00031 was applied. A spreadsheet tool for appendage drag evaluations was used to account for added drag created by the addition of

azimuthing pods, and an appropriate design margin of 8% was used according to NAVSEA design standards. From Figure 6, HSR(R) is capable of operating at a sustained speed at 20^+ knots and has a potential trial speed of 23 knots. It should be noted that if faster speeds become more desirable, a significant amount of additional power will be required; equally reductions in transit speed may offer reduced power system scope and cost. High speed was expected to not be a driving factor in a future HSR design, but currently no speed requirements have been formally defined.

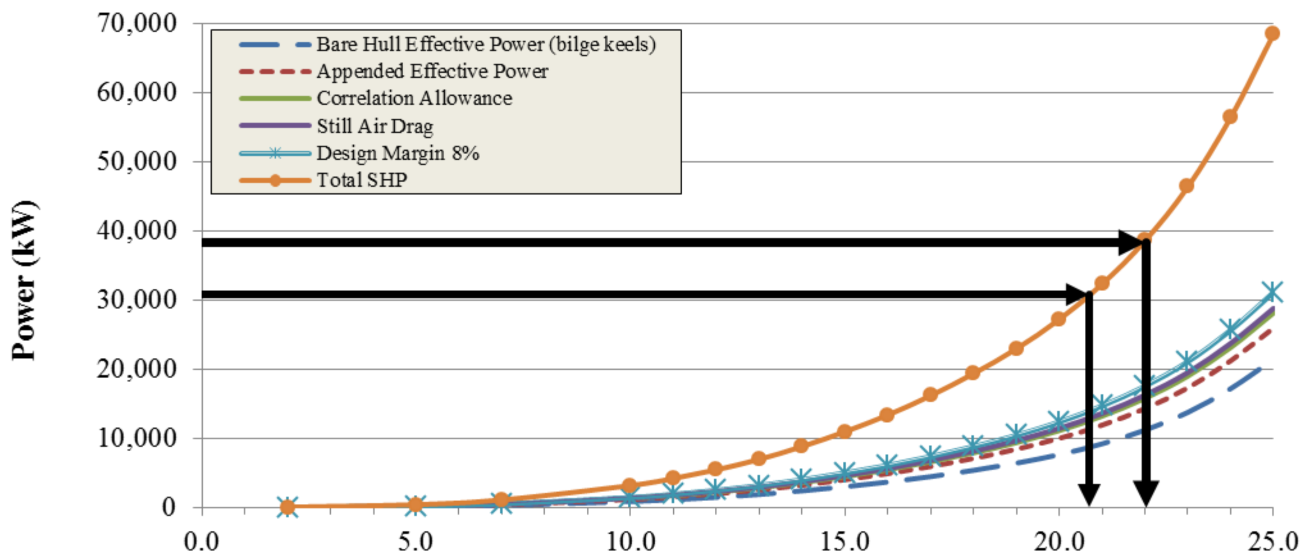

Figure 6: HSR(R) Speed-Power Curve

Electrical

The HSR(R) ship-service electrical load was derived from the consideration of electrical load data taken from the LPD-17, T-AGS 66 (an IPS naval auxiliary), and the *Mercy* Class. Different load cases were estimated for varying missions, operating speeds and climate conditions. The largest electrical load case was selected for a conservative estimate of the maximum required ship-service load. A maximum ship-service load was estimated at 3.62 MW_e. The total hotel load includes an 11% design margin as referenced from the NAVSEA margin policy. Additionally the emergency power maximum load was also predicted.

The total generating power required for the HSR(R) was estimated by combining the ship-service load (Table 12) with the total motor load seen at the azimuthing pods. Typical High Voltage Alternating Current (HVAC) electrical system losses were assumed along with representative estimates for propulsive efficiency. NAVSEA growth and power margins were also applied. The total estimated generating power required for sustaining a 20 knot speed was 41.2 MW_e.

Table 12: HSR(R) Non-Propulsive Loads

Group	Component	Max Power kW	Emergency kW	Launch		Cruise	
				Summer	Winter	Summer	Winter
200	Propulsion Plant	0.8	25.2	0.8	0.8	0.8	0.8
300	Electrical Plant	1,328.0	647.1	1,328.0	1,328.0	1,328.0	1,328.0
400	Command + Surveillance	64.4	22.2	64.4	64.4	41.5	41.5
500	Auxiliary Systems	1,434.0	397.2	1,434.0	1,434.0	1,303.1	1,303.1
510	Climate Control	676.5	157.3	676.5	676.5	639.0	847.1
600	Outfit and Furnishings	344.1	-	344.1	344.1	344.1	344.1
700	Marine Sanitation Device	75.1	-	75.1	75.1	75.1	75.1
800	Medical Storeroom	17.8	-	17.8	17.8	17.8	17.8
	Total (kW)	**3,264.3**	**1,091.8**	**3,264.3**	**3,264.3**	**3,110.4**	**3,318.5**
	Design Margin – 11% (kW)	359.1	120.1	359.1	359.1	342.2	365.0
	Total (kW)	**3,623.4**	**1,211.9**	**3,623.4**	**3,623.4**	**3,452.6**	**3,683.6**

Several machinery systems were analyzed to determine a suitable power system. An IPS system was selected due to the HSR(R)'s requirement for high ship-service loads while alongside or at anchor. This offered a way of minimizing the overall installed power while providing a highly redundant, and flexible power system that could be matched to an electric pod system, which in term could offer better low speed maneuverability, and reduce the need for tug support in austere locations,. Significant fuel and maintenance savings should be achievable through life when compared to the current *Mercy* Class.

Four 18 cylinder (8.64MW each) and two 8 cylinder (3.84 MW each) medium-speed (720rpm) diesel generators (D-Gs) are proposed. This system offers a combined power of 42.24 MW and hence 2.4% more power than the predicted maximum margined load. The small D-G units are matched to anchor or alongside likely power requirements, allowing better engine efficiency, and lower fuel costs and hence longer alongside endurance. A seventh small D-G unit was selected to support the required emergency power of 1.21 MW. The emergency generator would supply non-propulsion loads to ensure vital medical operations and an uninterruptable power supply. A schematic of the machinery arrangement is found in Figure 7.

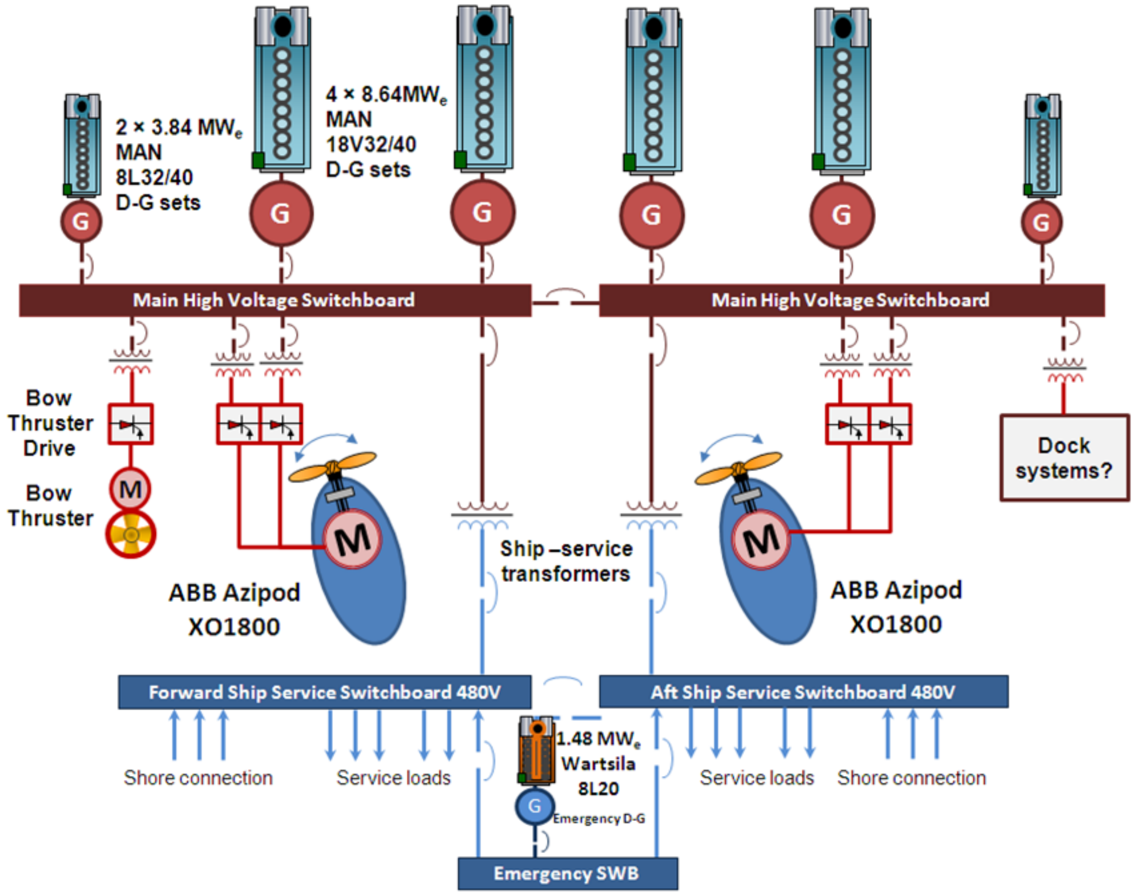

Figure 7: HSR(R) Machinery Schematic

Endurance

The following graphs show data for the hourly fuel burn as well as the range in nautical miles per LT of fuel for HSR(R) at different speeds. All calculations were derived from NAVSEA Design Data Sheet 200 – Rev 1 (Department of the Navy, Naval Sea Systems Command, 2011). As shown in Figure 8, the ship requires an exponentially greater amount of fuel to operate at the sprint speed of 22 knots rather than at 18 knot cruise speed.

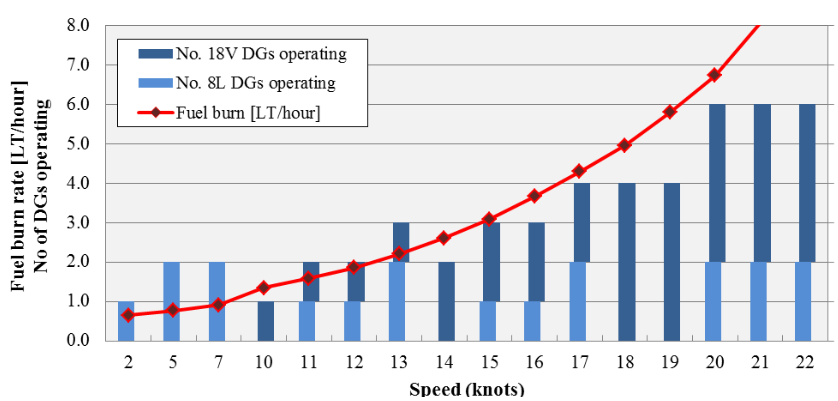

Figure 8: Hourly Fuel Burn (cruise ship service load)

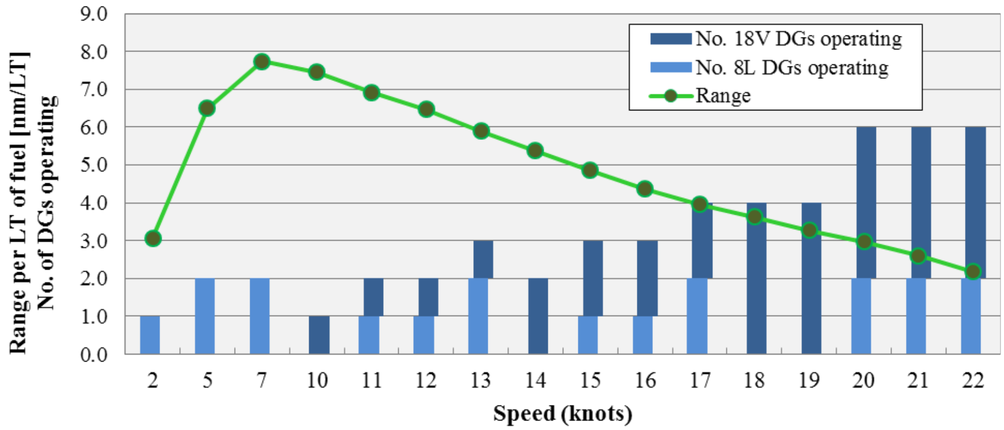

Figure 9: Range per LT Fuel (cruise ship service load)

Figure 9 shows the range the HSR(R) can achieve for varying speeds. An important characteristic of this plot is that the optimal speed for the HSR(R) is at 7 knots. At this speed the ship can travel much farther, however even at 15 knots the range of the HSR(R) is significant. From this plot the sprint range with full fuel tanks (about 3,600 LT) without refueling is around 7,200 nautical miles. This plot gives information for different missions and shows the trade-off between speed of arrival on a mission and the fuel required, or the range achievable.

Figure 10 shows the number of days the ship is able to operate at anchor after traveling a certain transit distance. For a humanitarian assistance mission where there is a set time at anchor as well as no requirement to sprint to a destination, the HSR(R) could travel at a slower speed to increase its time on mission without re-fueling.

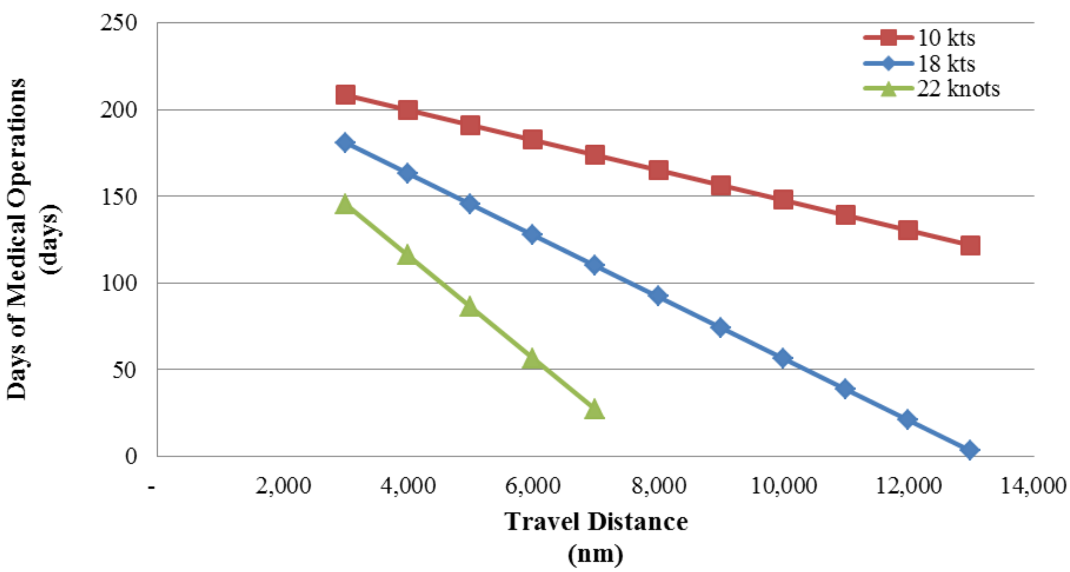

Figure 10: Predicted Unrefueled Maximum Time on Station (impact of transit to station)

Structural Design

Affordability is likely to be a fundamental challenge when attempting to replace the current T-AH class. The HSR(R) concept is a significantly smaller ship than the current T-AH's due to the more efficient use of available volume possible in a dedicated design, however, minimizing build and hence acquisition costs will be an important consideration. The primary focus of the structural analysis was, therefore, to explore structural design features that affect producibility.

In shipbuilding, labor costs can be as much as 60% of the total production cost and up to half of all labor hours are spent welding (Dong, 2010). The quality of welds can vary greatly when traditional arc welding is performed because it is wholly dependent on the skill and experience level of individual welders. The adoption of techniques such as friction stir welding will allow repeatability to be increased dramatically and reduce the now frequent need for post-production weld repairs. With either method, reducing the number of welds required in a ship structure will improve its producibility, reduce labor hours, and hence production costs.

The HSR(R) concept is not required to meet warship survivability requirements in areas such as vulnerability to underwater explosion, and hence is not required to be built under the same Naval Vessel Rules that the parent LPD-17 hull design was designed to. Rather, as an MSC ship, it falls under ABS Steel Vessel Rules which detail the guidelines for designing to commercial standards. Under these guidelines, the welding requirement can be decreased significantly by increasing stiffener spacing on the decks, bulkheads, and shell. Figure 11 shows the relationship between stiffener spacing and the plate thickness required under the ABS Steel Vessel Rules.

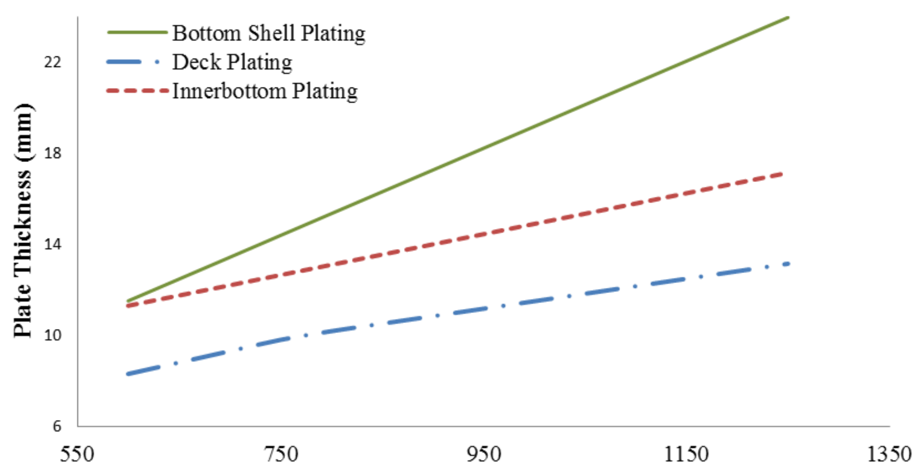

Figure 11: Stiffener Spacing Sensitivity Amidships

Although this results in an increase in associated plate thicknesses and therefore overall structural weight, the increase in material cost is insignificant compared to the broader benefits of improved producibility. In addition to decreasing the amount of welding needed, plate distortion decreases as thickness increases; this shortens the process of preparing and aligning

plates for welding. The standardization of stiffener and plate sizes becomes more feasible as well. For example, Table 13 compares the number of plate sizes required if the HSR(R) were designed to the military guidelines used in the design of the LPD-17 with the requirements of commercial guidelines. By conservatively sizing plates according to the closest standard plate size, the number of different plates can be reduced by 50%. Designing to commercial standards not only decreases shipyard production costs, but also expands the pool of shipyards eligible to bid on the contract.

Table 13: Number of HSR(R) Plate Sizes

	Deck plate sizes	Shell plate sizes	Longitudinal plate sizes
Military specification	7	6	6
Commercial Specifications	3	4	3

Weight Estimates

The structural design, mission, machinery, and arrangements of the HSR(R) differ significantly from the LPD-17 parent hull. Weights were therefore reassessed at the three-digit level to ensure a similar full load displacement was maintained. Several weight groups were scaled from the original LPD-17 weight data, using scaling factors based on changes to internal volume, generating capacity, and total accommodations as appropriate. It is noted that SWBS 100 weights have increased since the design includes producible structural design features.

Specific major equipment weights were calculated based on representative equipment for the ship needs; these included weights for the ships Diesel Generator sets and azimuthing electric pods. Additionally, specific weights for some of the medical equipment needed to carry out the mission were used in the weight analysis. Table 14 lists HSR specific weights used to calculate the overall displacement of the ship. HSR(S) weights are summarized in Table 15. A two-digit HSR(R) weight estimate is given in Appendix D.

According to NAVSEA guidelines, a preliminary design margin of 8% was added to the lightship weight and a 5% service life margin was added to the deadweight and the lightship plus the margin. Using these criteria, the full load displacement of the HSR(R) is consistent with a 23-foot draft for the LPD-17 class hull.

Table 14: HSR(R) Specific Equipment Weights

Additional items	Quantity	Weight per unit (LT)	Total weight (LT)
Medical Equipment			
CT Scan	1	3.2	3.2
Compress Melt Unit Mod 1	1	0.6	0.6
Crawford CB35SW Incinerator	2	5.5	11.0
Medical ISO Containers (full)	10	11.8	118.0
MRI	4	11.8	47.2
Oxygen Production Units	2	0.8	1.6
SteriMed Medical Processor	1	0.7	0.7
X-Ray	5	0.5	2.5
Ship Systems			
Azipods	2	289.0	578.0
Large Pulper	1	1.3	1.3
Plastic Waste Shredder	1	0.6	0.6
Solid Waste Shredder	1	0.6	0.6
Wartsila 18V32 Gensets	4	130.9	523.5
Wartsila 8L32	2	75.7	151.5
Water Production Unit	1	113.8	113.8
		TOTAL	**3,088.2**

Table 15: HSR(R) One-Digit Weight Summary

SWBS	Description	Weight (LT)
W 100	Hull Structures	10,335
W 200	Propulsion Plant	1,700
W 300	Electric Plant	1,200
W 400	Command & Control	300
W 500	Auxiliary Systems	2,500
W 600	Outfit & Furnishing	1,530
W 700	Armament	35
	Lightship Weight (w/o Margin)	17,600
	Lightship Weight (with 8% Margin)	**19,000**
F 800	Deadweight	4,860
	Full Load Displacement	**23,860**
M 900	Service Life Margin (5%)	1,200
	Displacement at End of Service Life	**25,060**

Stability

The LPD-17 is an extremely stable ship resulting in a very short roll period, which leads to snapping motions in waves. For the HSR(R) these short periods would be unacceptable for carrying out medical operations. The weight distribution of the HSR(R) also differs from the LPD-17 hull, with the heavy vehicle compartments replaced by patient wards. For this reason the intact stability of the ship was reevaluated.

From an analysis of the weight distribution, including the added superstructure and the aluminum deckhouse, the VCG was found to be 1.6 feet (0.49 m) higher on the HSR(R) than the parent hull form. This decreased the GM/B ratio. The hydrostatic values in Table 16**Error! Reference source not found.** were calculated using Paramarine. Paramarine was also used to develop a GZ curve of the righting arm, as shown in Figure 11**Error! Reference source not found.**. This analysis shows sufficient intact stability for the altered ship.

Table 16: HSR(R) Hydrostatics

Hydrostatics		
Trim BP	0.0 ft	[0.0 m]
Mean draught	23.0 ft	[7.0 m]
Draught AP	23.0 ft	[7.0 m]
Draught FP	23.0 ft	[7.0 m]
List or Loll Angle	0.0^{o}	
Displacement	25,116 LT	[25,470 mt]
Longitudinal Center of Gravity (LCG_s)	-347.4 ft	[-105.9 m]
Vertical Center of Gravity (VCG_s)	43.2 ft	[13.2 m]
Longitudinal Center of Buoyancy (LCB)	-347.4 ft	[-105.9 m]
Vertical Center of Buoyancy (VCB)	12.9 ft	[3.9 m]
Longitudinal Center of Floatation (LCF)	-392.0 ft	[-119.5m]
Immersion (TPI)	124.6 LT/in	[48.8 mt/cm]
Keel to metacenter – transverse (KM_t)	50.9 ft	[15.5 m]
Keel to metacenter – longitudinal (KM_l)	1,529.3 ft	[466.1 m]
Metacentric height – transverse (GM_t)	7.7 ft	[2.3 m]
Metacentric height – longitudinal (GM_l)	1,486.1 ft	[452.9 m]

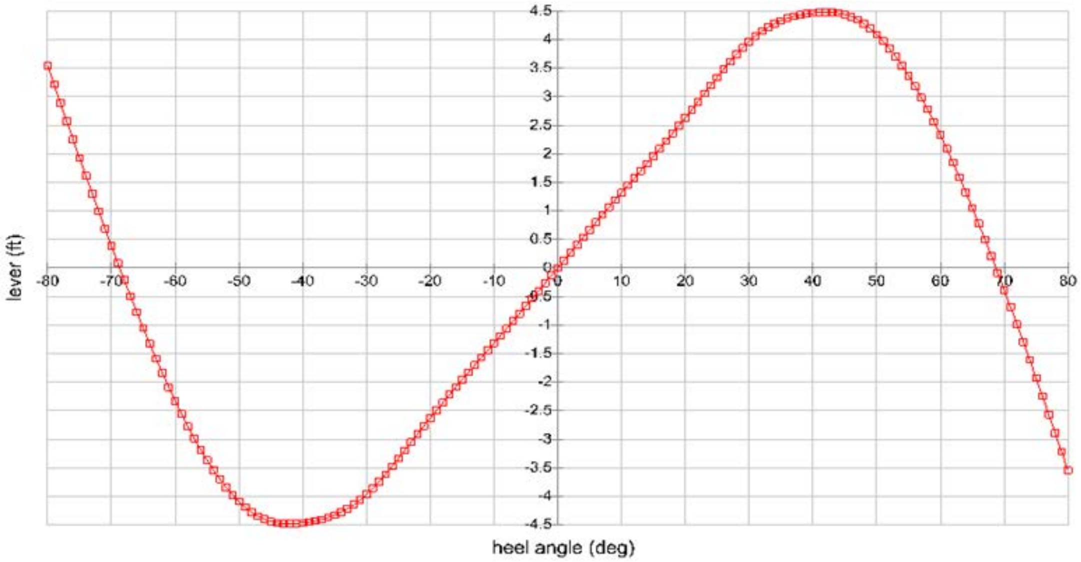

Figure 12: HSR(R) GZ Curve

Seakeeping

By selecting a monohull as the basic hull form, several inherent stability issues require definition. It is important not only to overcome these issues, but to also achieve motions that maximize the ability of the ship to operate as a functional hospital in the highest sea state possible.

A number of stabilizing systems can be recommended that will effectively control roll motions on the HSR. Both passive and active systems exist; a variety of stability enhancement mechanisms were researched and considered, including gyrostabilizers, anti-roll tanks, and active fins. The optimal solution will depend on cost, maintainability, required weight and internal volume. It is not possible at this stage to conduct an appropriate study of these options as no specific motion requirements could be identified for medical procedures. Equally it was not possible to compare the proposed HSR(R) design against the current motions of the *Mercy* Class, as no seakeeping data for the *Mercy* could be identified.

HSR(R) was analyzed using the Leading Edge Architecture for Prototyping Systems (LEAPS) environment Ship Motions Program (SMP) against helo operations criteria. The results shown in Table 17 show that HSR(R) motions are well below the criteria set for vertical accelerations and roll angle in Sea State 2. However, these results might require validation as the validity of SMP at zero speed is not fully understood.

Table 17: HSR(R) Helicopter Operations Criteria

	Criteria	SMP results - HSR(R)
Vertical accelerations - Flight deck (g's)	0.4	0.04
Vertical accelerations - Operating Rooms (g's)	0.4	0.02
Roll angle (degrees)	8.0	2.0

Conclusions

Summary

The need to replace the existing hospital ships is a rising concern for the U.S. Navy. As the USNS *Mercy* and USNS *Comfort* reach the end of their service life, the fleet will need to replace these ships with a modern, more efficient, and affordable hospital ship that will be able to efficiently satisfy the ship's missions. This project has produced a ship design concept that highlights a range of features that are likely to be desirable in a new hospital ship; it also presents a possible design solution as a basis for future work in this area.

The 25,000 LT HSR(R) design offers solutions to a number of issues that have been encountered with the existing *Mercy* Class. HSR(R) is a smaller ship that nearly meets the *Mercy* Class' actual capability in some missions. By designing a 500-bed capacity and using a different hull form, the HSR(R) has a shallower draft; the ship is then capable of accessing a wider range of ports as well as anchoring closer to shore during its missions. With the integration of both a well deck and flight deck, it provides an efficient system for patient transport by both sea and air, thus increasing patient throughput. It uses an integrated power system comprised of six diesel generator sets along with dual electric pod propulsors to improve maneuverability and reliability. Modern, flexible and higher capacity auxiliary systems for both freshwater and oxygen production have been selected to meet the demands of hospital operations. The HSR(R) is designed to meet ABS Steel Vessel Rules in order to commercialize the structure and present a producible, affordable solution. Finally, the general arrangements have been designed in order to improve the flow of patients onboard.

The outfit of HSR(R) offers flexibility in the utilization of available spaces and can be tailored to different missions of the hospital ship: humanitarian assistance, disaster relief, and combat casualty care missions. By incorporating medical ISO container systems and large flex spaces, the design can provide modular medical facilities in response to the variety of missions. Additionally, the general arrangements are organized for good patient flow and optimization of space location.

Recommendations

The HSR(R) provides a solid base for the future design development of a new hospital ship. Although the concept has undergone two iterations, several opportunities for future work are recommended.

While solutions have been identified for improving the maneuverability of HSR(R), identifying the possible improvements for zero-speed seakeeping are undefined. For seakeeping analysis, it is difficult to draw conclusions from the results due to the lack of information about *Mercy* Class ship motions. HSR(R) has listed means of reducing motions at anchor, but the seakeeping requirement needs to be quantified so that a trade study of other motion-damping systems can be conducted.

Additionally, the patient transfer interface via well deck has not been fully determined. Even though the stern dock space and access to the internal spaces within the ship are present, the arrangement of how surface vehicles will transit, secure, and transport patients from the vehicles to HSR(R) needs further study.

The parent hull form also requires optimization since the present tunnel stern is not an efficient solution to house azimuthing propulsors; a flat aft-body shape is required for clean water flow to reach the tractor pods.

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CAPT Daniel Ryan	MSC
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John Zarkowsky	BUMED M5B4

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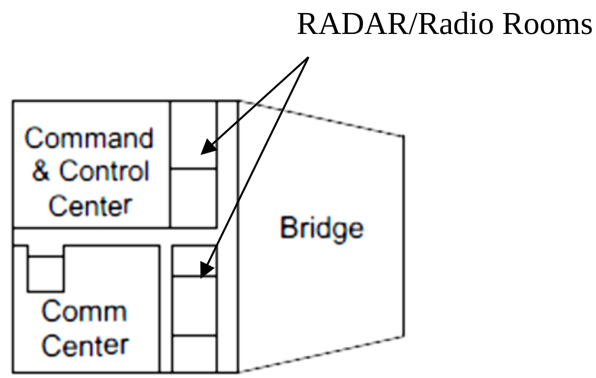
Dong, P.; "Ship Production" *UNO NAME Ship Production – Course Notes;* 2010.

Appendices

Appendix A: General Arrangement

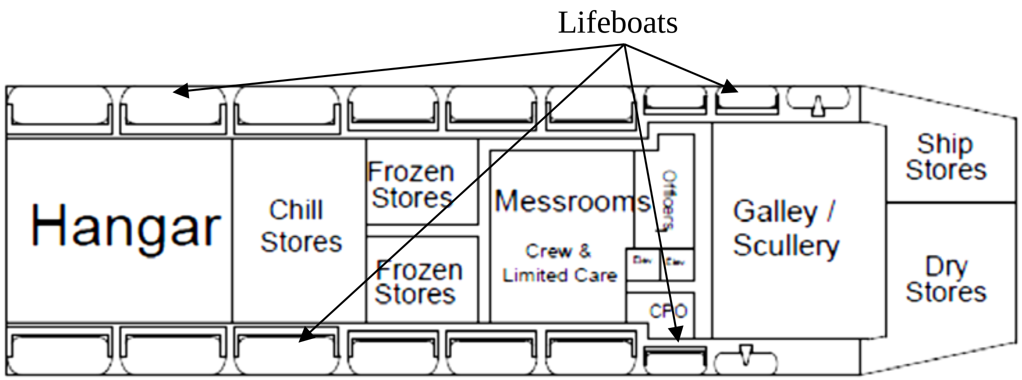
Drawings scaled 1 inch = 75 feet

Red areas indicate separated fire zones

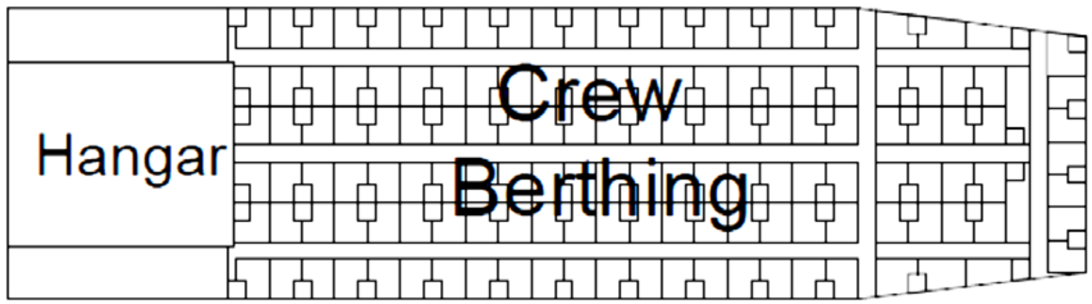


06 Level
114.8 ft ABL

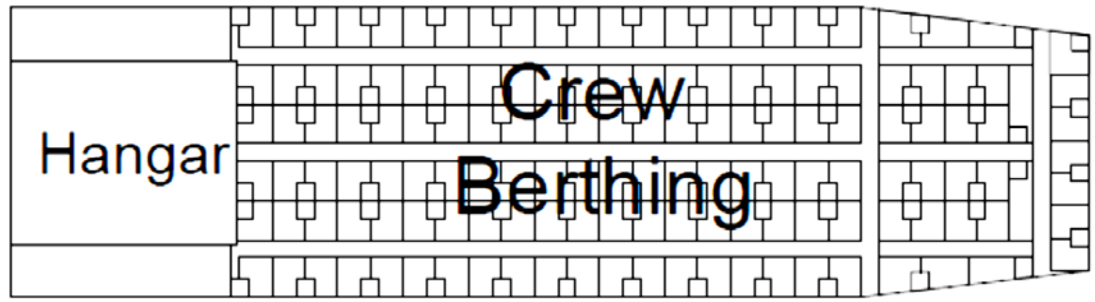
05 Level
106.3 ft ABL



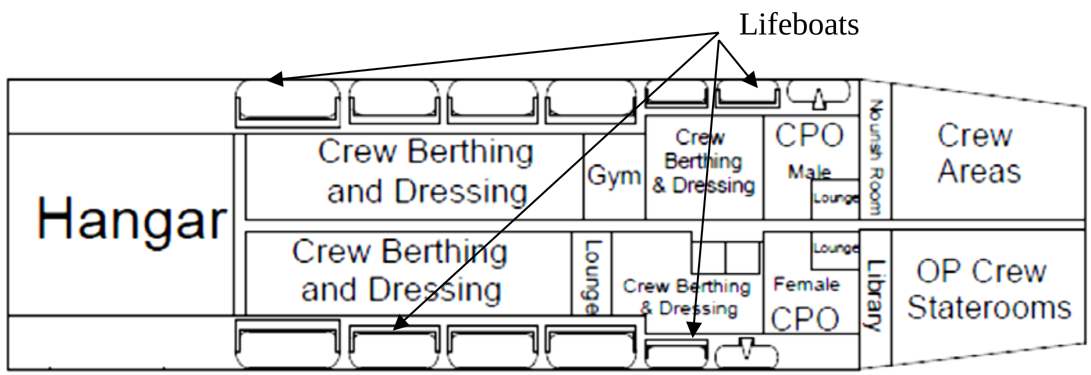
04 Level
97.8 ft ABL



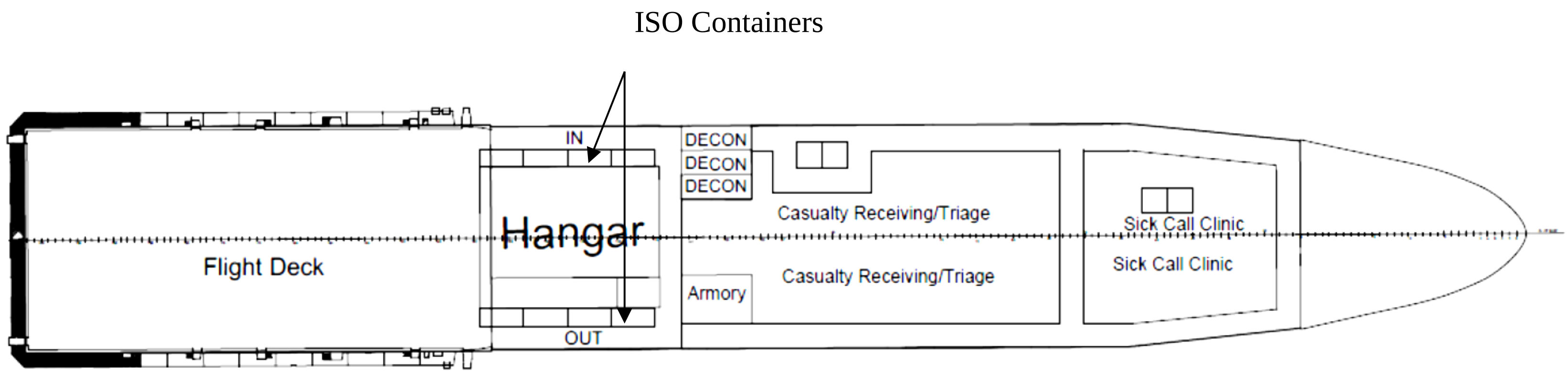
03 Level
88.6 ft ABL



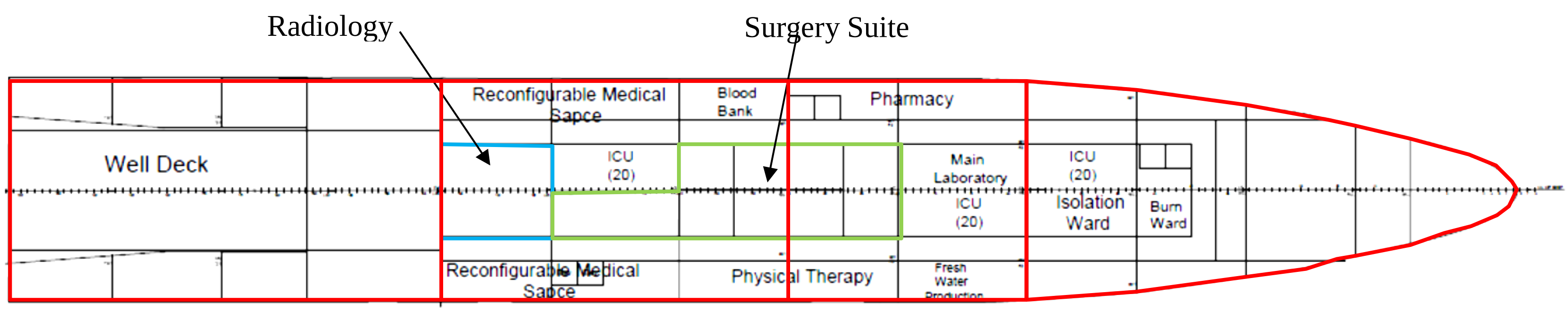
02 Level
79.4 ft ABL



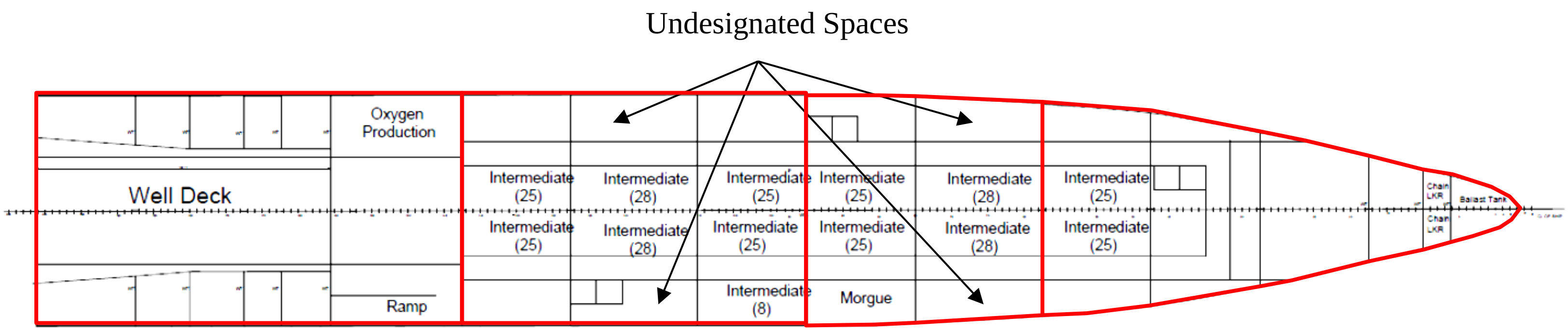
01 Level
70.9 ft ABL



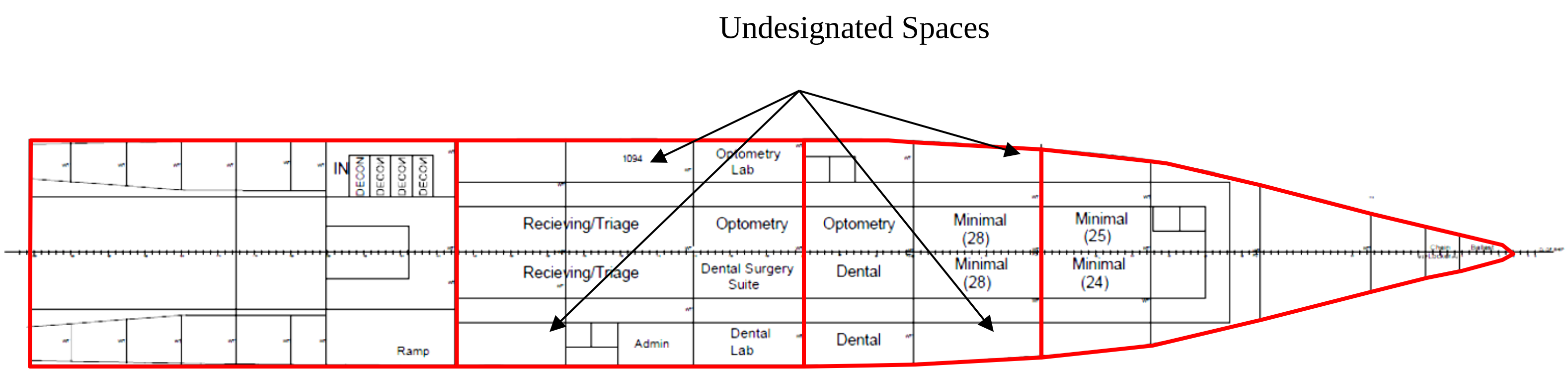
Main Deck
62.3 ft ABL



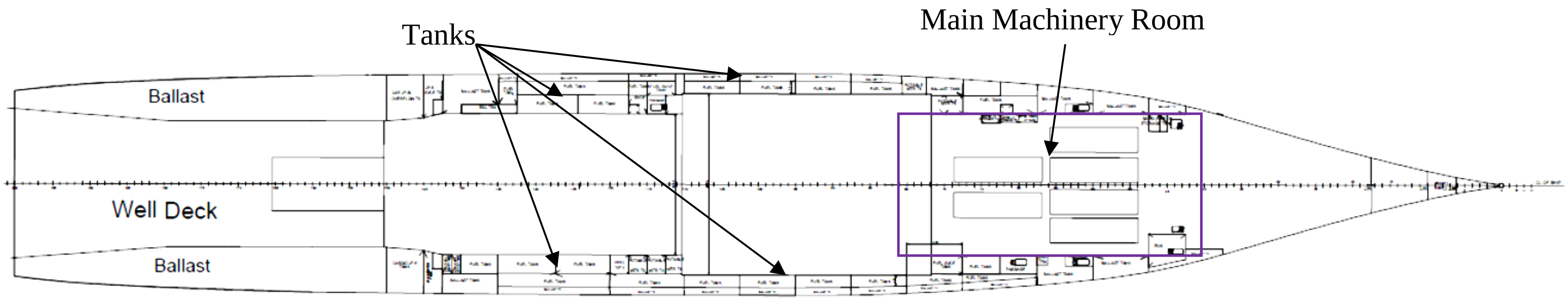
2nd Deck
53.1 ft ABL



3rd Deck
44.6 ft ABL



1st Platform
35.4 ft ABL



2nd Platform
25.6 ft ABL

Appendix B: Amphibious Support

Table B- 1: Patient Unloading/Loading Estimates

HIGH-SPEED Hovercraft	ACV [mins]	ORDER	# Patients Walking Wounded 9	# Patients Stretcher 16	# Patients Walking Wounded 10	# Patients Stretcher 17	# Patients Walking Wounded 11	# Patients Stretcher 18
@ Ship/SeaBase								
Approach & moor	5	SLOW	5		5		5	
Patient Load - Walking Wounded	2	SLOW	18		20		22	
Patient Load - Stretcher	3	SLOW	48		51		54	
Cast off & Clear	2	IDLE	2		2		2	
LOAD TIME	**SUB-TOTAL**		73		78		83	
@ Landing Point								
Land/Prep	2	SLOW	2		2		2	
Patient Unload - Walking Wounded	2	IDLE	18		20		22	
Patient Unload - Stretcher	3	IDLE	48		51		54	
Cast off & Clear	2	SLOW	2		2		2	
OFFLOAD TIME	**SUB-TOTAL**		70		75		80	
LOAD + OFFLOAD TIME [mins]	**TOTAL**		**143.00**		**153.00**		**163.00**	

Table B- 2: Estimated Patient Transfer Time via Small Boats

		Distance [nm] before FULL			
MAX SPEED[kts]	**20**	0.25	*Load / Off-Load Times (Non-ACV)*		
TRANSIT TO/FROM DISTANCES [nm]	**[mins]**	**ORDER**	**# Patients 25**	**# Patients 27**	**# Patients 29**
5	*6.0*	HALF	*143.00*	*153.00*	*163.00*
(one way only)	*27.0*	FULL			
Round Trip Total (min) =	***33.0***	***Combined***	***176***	***186***	***196***
12	*6.0*	HALF			
(one way only)	*69.0*	FULL			
Round Trip Total (min) =	***75.0***	***Combined***	***218***	***228***	***238***
20	*6.0*	HALF			
(one way only)	*117.0*	FULL			
Round Trip Total (min) =	***123.0***	***Combined***	***266***	***276***	***286***
26	*6.0*	HALF			
(one way only)	*153.0*	FULL			
Round Trip Total (min) =	***159.0***	***Combined***	***302***	***312***	***322***

**Assumptions:*
1.) Require 0.25nm @ Ordered Speed = HALF prior to/post the Approach & Clear
2.) Remainder of transit @ Ordered Speed = FUL
3.) Times/Ordered Speeds for Load & Off-Load as above

Table B- 3: Seated Wounded Patient Calculation

Available area	5.3 × 23.5’ = 125.3 feet^2
95% man sitting, one leg propped; 6” clearance	11.4 feet^2
Total Patients	125 feet^2 / 11.4 feet^2 × 23.5’ = **11**

Table B- 4: Area Estimates for Patient Transport

	Length (ft)	Width (ft)	Height (ft)	Area (ft^2)
95% man standing	2.2	1.0	6.1	2.1
95% man standing with 6” clearance				3.9
95% man sitting	2.2	2.7	4.6	6.0
95% man sitting with 6” clearance				8.7
95% man sitting (one leg propped)	2.2	3.7	3.2	8.2
95% man sitting (one leg propped) with 6” clearance				11.4

Table B- 5: Deck Dimensions

	Length(ft)	Width (ft)	Height (ft)	Deck area (ft^2)
Deck Dimensions	23.5	9.5	7	223.3
Stretcher Dimensions	7.2	2.1	N/A	14.9

Appendix C: Sea-to-Ship Transfer Options

Table C- 1: Various Solutions for Sea-to-Ship Transfer

System	Description	Advantages	Disadvantages
SEABEE	A platform at the stern of the ship lowers from main deck to below the waterline, allowing smaller craft to move onto platform and be lifted to the main deck. Design originally used to lift barges.	• Removes large ballast system • Sized to ships being lifted • Unload site can be at any deck	• Poor hydrodynamic characteristics • Large structural requirement • Patient unloading area uncovered
Current wet Well Deck	An opening at the stern is flooded by ballasting the aft end of the ship to well below the design waterline, allowing craft to power into the opening on the ship.	• No redesign needed • Adaptable to new small craft options • Current arrangement brings patients into the ship at casualty receiving • Patient unloading in sheltered area	• Large ballast system to lower deck below waterline • Large structure required to support stern opening • Larger than the HSR requires
Dry Well Deck	An opening at the stern that is not flooded by ballasting system. Provides a large passageway to potentially receive patients from ambulance air cushioned vehicles. Displacement vessels must unload onto stern door acting as a ramp/ pontoon	• Large ballast system not required • Current arrangement brings patients into the ship at casualty receiving • Patient unloading in sheltered area	• Limited to Air cushioned vehicles for internal access • Large structure required to support stern opening • Interface between dry well deck and ambulance vehicles is undefined
Reduced size Well Deck	Same concept as original LPD-17 well deck with a significant reduction in size to accommodate necessary craft for the hospital ship instead of an LCAC.	• Patients are brought onto the ship at casualty receiving • Adaptable to changing small craft • Patient unloading in sheltered area • Sized to the requirement of the hospital ship	• Large ballast system required • Large structural build near stern
Davit System	Two or more crane type lift points mounted to the deck allowing small craft to be moved over the edge of the deck; raises or lowers the small craft by attaching to lift points on the craft	• Davits can be installed on any deck • Minimal structure required • Minimal need for any hull openings • Minimal time required to launch a single craft • Multiple launch sites	• Difficult to unload patients from small craft • Size/weight of small craft limited by installed system • Patient unloading probably uncovered
'WellBee'	Combination of a SEABEE and Well Deck allowing the well deck platform to lower below the waterline allowing the well to operate as a wet well without the need for a ballast system.	• No ballast system required specifically for well • Adaptable to new small craft • Sized to the requirement of the hospital ship • Patient unloading area covered	• Requires advanced mechanical system to raise/lower platform below waterline • Opening in the stern of the ship • High risk technology

Appendix D: HSR(R) Two-Digit SWBS Weight Summary

Table D- 1: HSR(R) Two-Digit SWBS Weight Summary

SWBS		Weight (LT)
W100	**HULL STRUCTURES**	**10,334.2**
W110	SHELL + SUPPORTS	3,317.1
W120	HULL STRUCTURAL BULKHDS	2,360.3
W130	HULL DECKS	1,683.9
W140	HULL PLATFORMS/FLATS	1,465.6
W150	DECK HOUSE STRUCTURE	528.2
W160	SPECIAL STRUCTURES	560.3
W170	MASTS+KINGPOSTS+SERV PLATFORM	0.0
W180	FOUNDATIONS	418.2
W190	SPECIAL PURPOSE SYSTEMS	0.5
W200	**PROPULSION PLANT**	**1,700.7**
W210	ENERGY GEN SYS (NUCLEAR)	0.0
W220	ENERGY GENERATING SYSTEM (NONNUC)	0.0
W230	PROPULSION UNITS	675.0
W240	TRANSMISSION+PROPULSOR SYSTEMS	684.9
W250	SUPPORT SYSTEMS	132.3
W260	PROPUL SUP SYS- FUEL, LUBE OIL	57.4
W290	SPECIAL PURPOSE SYSTEMS	151.1
W300	**ELECTRIC PLANT, GENERAL**	**1,196.6**
W310	ELECTRIC POWER GENERATION	67.8
W320	POWER DISTRIBUTION SYS	621.0
W330	LIGHTING SYSTEM	110.0
W340	POWER GENERATION SUPPORT SYS	288.9
W350	GROUNDING AND BONDING	0.0
W390	SPECIAL PURPOSE SYS	108.8
W400	**COMMAND & CONTROL**	**299.0**
W410	COMMAND+CONTROL SYS	74.7
W420	NAVIGATION SYS	7.9
W430	INTERIOR COMMUNICATIONS	143.3
W440	EXTERIOR COMMUNICATIONS	45.7
W450	SURF SURV SYS (RADAR)	4.1

SWBS		Weight (LT)
W460	UNDERWATER SURVEILLANCE SYSTEMS	0.0
W470	COUNTERMEASURES	0.0
W480	FIRE CONTROL SYS	0.0
W490	SPECIAL PURPOSE SYS	23.2
W500	**AUXILIARY SYSTEMS, GENERAL**	**2,491.6**
W510	CLIMATE CONTROL	701.6
W520	SEA WATER SYSTEMS	435.2
W530	FRESH WATER SYSTEMS	211.1
W540	FUELS/LUBRICANTS,HANDLING+STORAGE	103.5
W550	AIR,GAS+MISC FLUID SYSTEM	222.2
W560	SHIP CNTL SYS	0.0
W570	UNDERWAY REPLENISHMENT SYSTEMS	29.8
W580	MECHANICAL HANDLING SYSTEMS	414.2
W590	SPECIAL PURPOSE SYSTEMS	373.9
W600	**OUTFIT+FURNISHING,GENERAL**	**1,538.0**
W610	SHIP FITTINGS	100.0
W620	HULL COMPARTMENTATION	351.4
W630	PRESERVATIVES+COVERINGS	543.3
W640	LIVING SPACES	176.6
W650	SERVICE SPACES	89.2
W660	WORKING SPACES	128.5
W670	STOWAGE SPACES	133.3
W690	SPECIAL PURPOSE SYSTEMS	15.8
W700	**ARMAMENT**	**36.4**
W710	GUNS+AMMUNITION	8.3
W720	MISSLES+ROCKETS	0.0
W730	MINES	0.0
W740	DEPTH CHARGES	0.0
W750	TORPEDOES	0.0
W760	SMALL ARMS+PYROTECHNICS	6.7
W770	CARGO MUNITIONS	10.0
W780	AIRCRAFT RELATED WEAPONS	0.0
W790	SPECIAL PURPOSE SYSTEMS	11.5
800	**DEADWEIGHT**	**4,863.2**

SWBS		Weight (LT)
F10	SHIPS FORCE	173.9
F20	MISSION RELATED EXPENDABLES+SYS	20.9
F30	STORES	205.1
F40	LIQUIDS, PETROLEUM BASED	3,906.0
F50	LIQUIDS, NON-PETRO BASED	289.3
F60	CARGO	267.9
900	**MARGINS**	**0**
M11	DESIGN + BUILDING MARGINS	0
M21	PRELIMINARY DESIGN MARGINS	8%
M26	SERVICE LIFE MARGIN (SURFACE SHIP)	5%
	LIGHTSHIP	**19,004.1**
	TOTALS	**25,060.6**

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